Life evolved in the ocean (as it was then)

Solute composition of average sea water

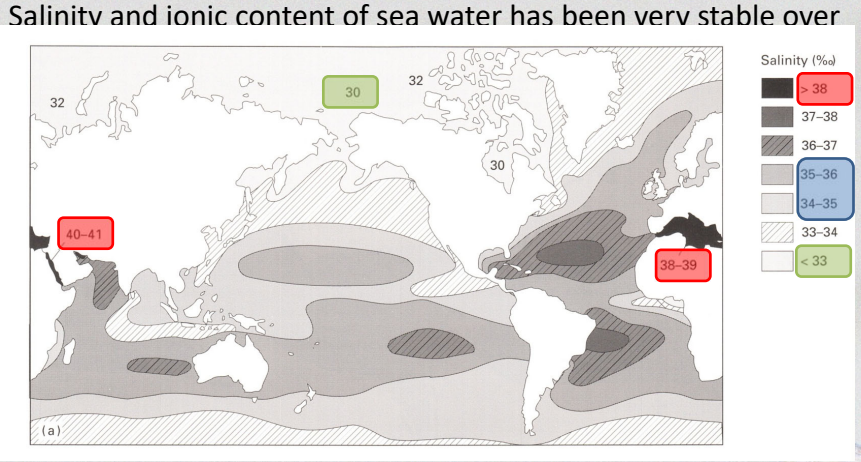
Component	mmol per litre sea water	g per litre sea water
Na	470	10.8
K	10	0.39
Mg	54	1.30
Ca	10	0.41
Cl	548	19.4
SO_4	28	2.7
HCO_3	2	0.14
Total osmotic concentration		**1000-1100 mOsm/kg**

"salt"

1

Salinity Variation around 35‰ (ppt) (= 1100 mOsm)

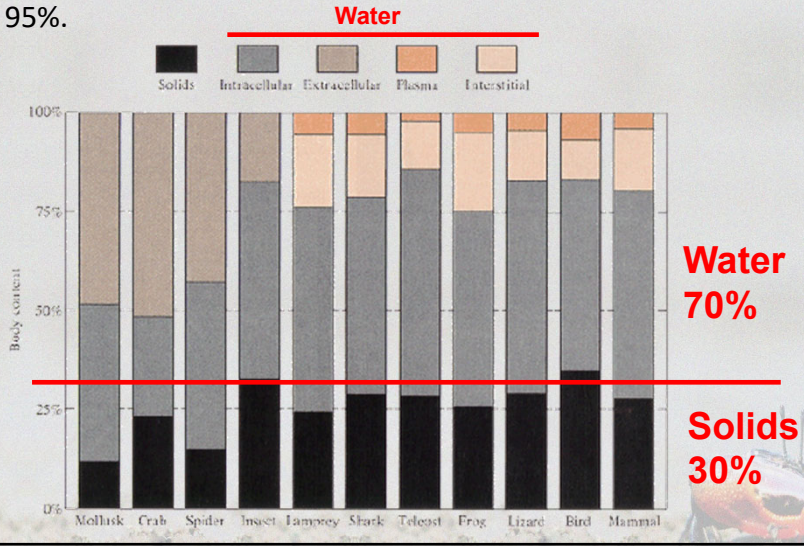
Salinity and ionic content of sea water has been very stable over



2

Body waterof animals

About 70% of an animal is water, ranging from about 60% to about 95%.

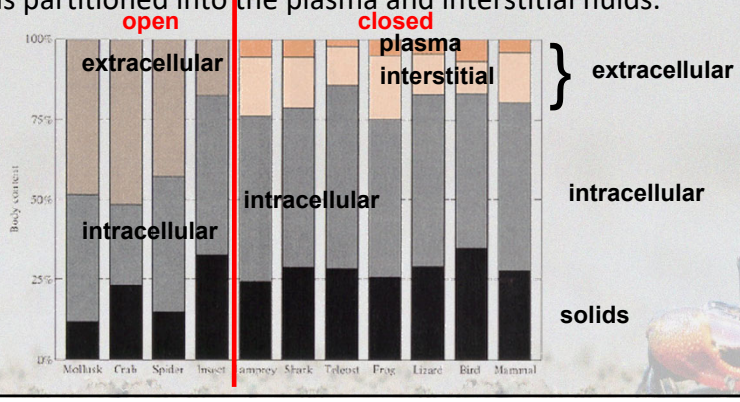


3

Body water

The water is distributed between the intracellular space and the extracellular space.

For animals with a closed circulatory system, the extracellular space is partitioned into the plasma and interstitial fluids.



4

Body Solutes

The intracellular and extracellular fluids contain various solutes that make up the total osmotic concentration.

The total osmotic concentration of the intracellular and extracellular fluids must be equal [at equilibrium] for animal cells.

The major solutes are:

- Cations (mainly Na+ and K+)
- Anions (mainly Cl-)
- Urea in some animals
- Other solutes make up the solute gap

5

Composition of marine Animal blood (extracellular)

Osmotic Concentration

Table 9.3 Osmotic concentration of marine animals' body fluids.

Phylum/genus	Osmotic concentration (mOsm)
Cnidaria	
Aurelia	1050
Mollusca	
Sepia	1160
Eledone	1061
Mytilus	1148
Annelida	
Arenicola	1120
Neanthes	1108
Crustacea	
Carcinus	1100
Ligia	1220
Nephrops	1108
Chelicerata	
Limulus	1042
Echinodermata	
Echinus	1065
Chordata	
Elasmobranch fish	
Scyllium	1075
Squalus	1096
Teleost fish	
Paralichthys	337
Gadus	308
Sea water	1000–1050

6

Ion composition of marine invertebrate blood (extracellular)

Ions (% of SW)

≈ 100%!

Most marine animals are iso-osmotic and iso-ionic

Most marine animals are iso-thermal

This tends to simplify their physiological requirements for homeostasis

Table 9.4 Ionic composition of marine animals' body fluids given as percentages relative to sea water.

Phylum/ species	Ion Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}
Cnidaria						
*Aurelia**	99	106	96	97	104	47
Mollusca						
Pecten	100	130	103	97	100	97
*Sepia**	93	205	91	98	105	22
*Loligo**	95	219	101	102	103	36
Annelida						
Arenicola	100	104	100	100	100	92
Aphrodite	99	103	100	101	99	92
Sipuncula						
Phascolosoma	104	110	104	69	99	91
Crustacea						
Maia	100	125	122	81	102	66
Carcinus	110	118	108	34	104	61
Nephrops	113	77	124	17	99	69
Echinodermata						
Marthasterias	100	111	101	98	101	100
Echinus	99	100	101	99	99	99
Urochordata						
*Salpa**	100	113	96	95	102	65

* Indicates a pelagic species.

7

Phylum/ group	Marine benthic	Marine pelagic	Freshwater	Terrestrial	Parasitic
Porifera	++	l			
Cnidaria	++	++	+		
Ctenophora		++			
Platyhelminthes	+	+	++	+	++
Nemertea	++	l	+	+	
Nematoda	++		++	++	++
Acanthocephala					++
Rotifera	+	+	++		r
Mollusca	++	+	++	++	r
Annelida	++	+	++	+	+
Pogonophora	+	l			
Sipuncula	+	l			
Priapulida	+	l			
Arthropods					
Crustacea	++	++	++	++	r
Arachnida	r		+	++	++
Insecta			++	++	++
Onychophora				+	
Bryozoa	++	l	+		
Brachiopoda	+	l			
Echinodermata	++	lr			
Urochordata	++	+			
Chordates					
'Pisces'	++	++	++		
Amphibia	r		+	+	
Reptilia		+	+	++	
Aves		(+)	(+)	++	
Mammalia		+	+	++	

++, Common; +, present; r, rare; l, larvae only.

8

Solute Compartment Differences

seawater

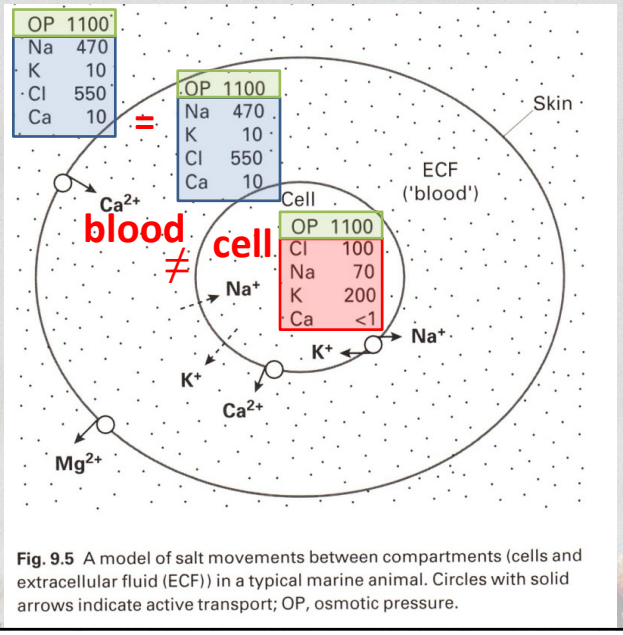


Fig. 9.5 A model of salt movements between compartments (cells and extracellular fluid (ECF)) in a typical marine animal. Circles with solid arrows indicate active transport; OP, osmotic pressure.

9

Excretion versus Elimination

EXCRETION: Removal of water/solutes that once were part of the body pool e.g. urine.

ELIMINATION: Loss of materials from the gut that had never been absorbed into the body fluids e.g. faeces

but some parts of the faeces are excreted products

10

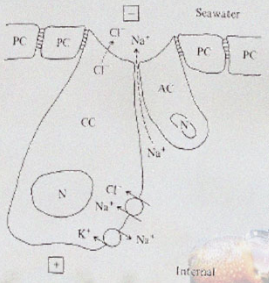
Epithelial excretory organs

The epithelial body surface is commonly used as an excretory organ, to actively transport specific solutes and control osmotic water flux.

Skin and gills are examples of such epithelial excretory organs.

Teleost fish gills contain chloride cells for active Cl^- (and passive Na^+) transport either:

- out of the body fluids (marine fishes)
- or into the body fluids (freshwater fishes)



11

Tubular excretory organs

Tubular excretory organs are more complex, internal organs.

They form a solution from the body (coelomic or blood) fluids, modify it, then excrete it as urine through a pore to the exterior.

There are three basic types of tubular excretory organs:

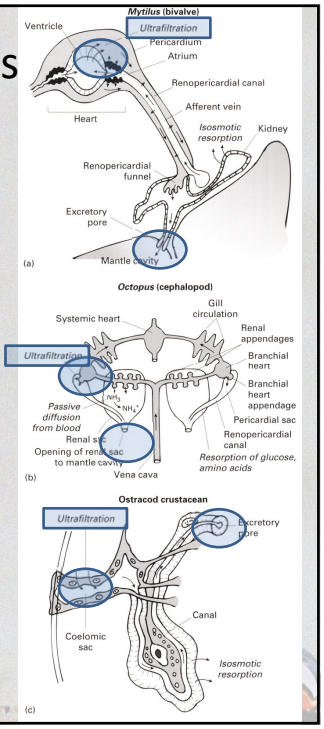
- protonephridia and metanephridia
- coelomoducts – mesodermal (develops from coelom lining) (including the vertebrate nephron, but these may be metanephridia!)
- Malpighian tubules

12

Simple Excretory Requirements - Marine invertebrates

- Relatively simple “kidneys”
- No major solute/ionic imbalances to deal with
- Excretory waste is NH3 which is permeable and highly soluble, but leads to high water loss

- All have 3 basic common characteristics



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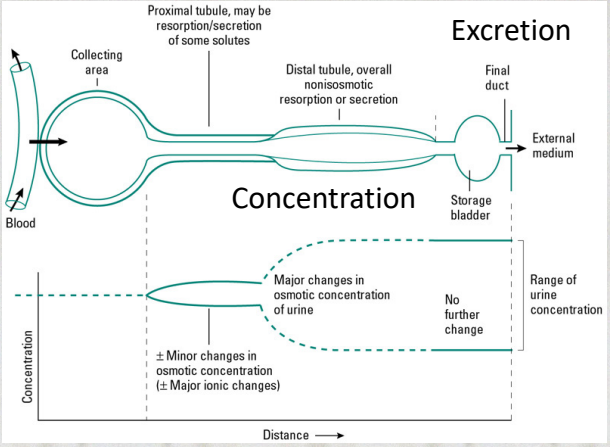
Simple Excretory Requirements - Marine invertebrates

Filtration



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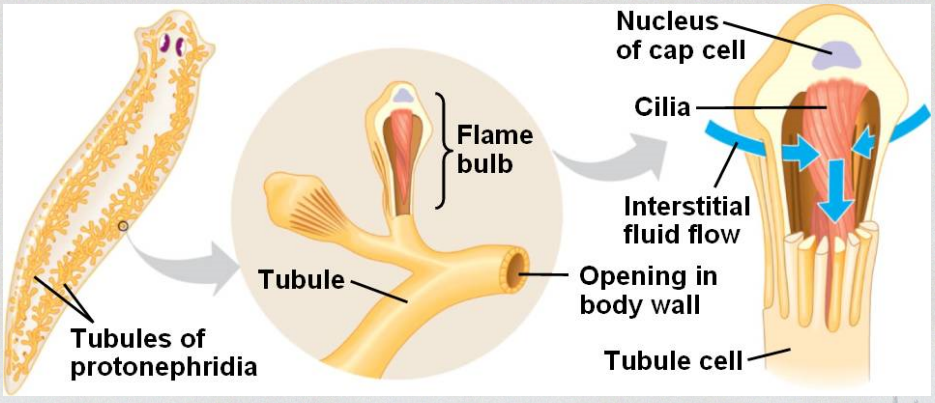
Protonephridia – planarian flatworm



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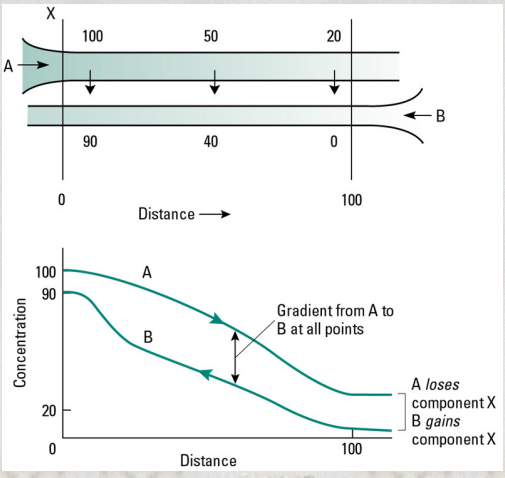
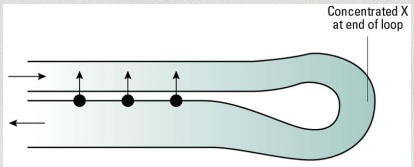
How to conserve water: more complex nephridial structures

Countercurrent exchanger - passive



Countercurrent multiplier - active



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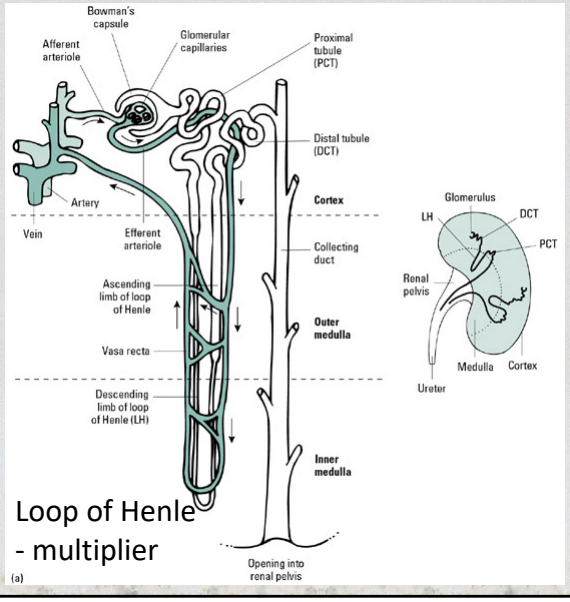
The mammalian Nephron



Loop of Henle
- multiplier

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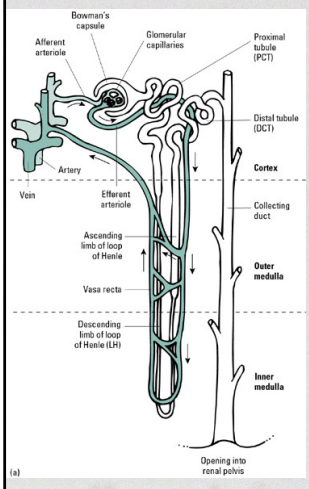
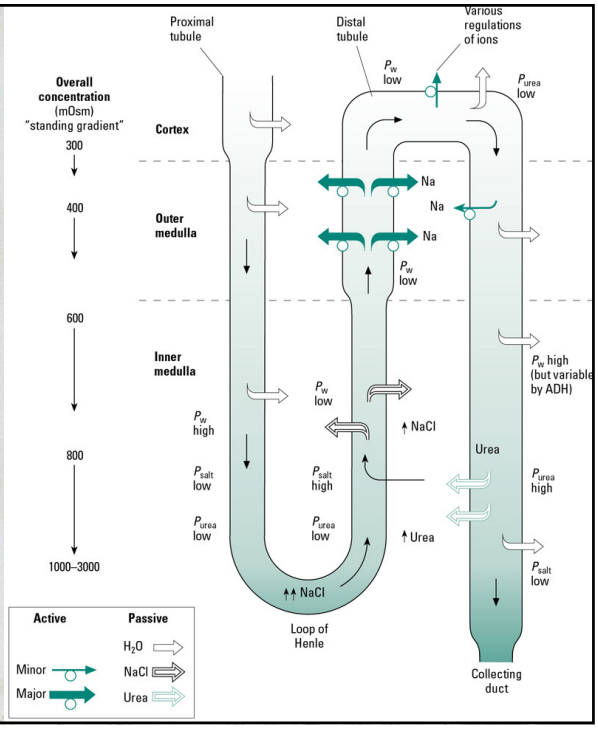
Mammalian nephron





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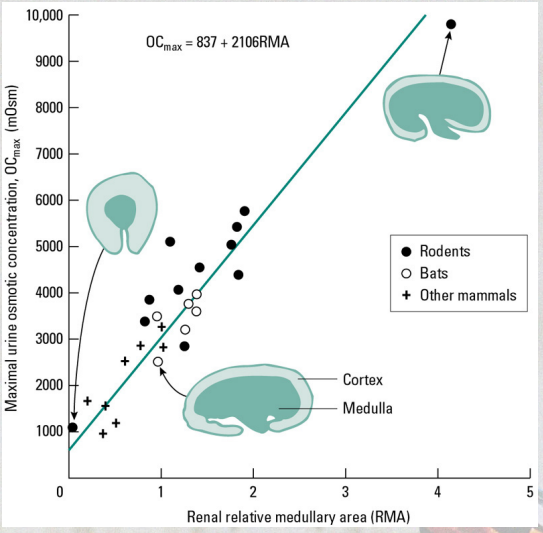
Kidney size correlates with maximal urin concentration

The medulla size is a measure of the length of the loop of Henle